GAS DISTRIBUTOR FOR A REACTOR

The present invention relates to a sparger system for
use in a reactor. In particular, the invention relates to
gas sparger system suitable for a reactor to be used for
exothermic reactions such as Fischer-Tropsch reactions,
5   as well as to hydrocarbons and fuels derived from these
hydrocarbons, which can be made by the hydrogenation of
carbon monoxide in a process using the reactor and the
sparger system.

The Fischer-Tropsch process is often used for the
10   conversion of hydrocarbonaceous feed stocks into liquid
and/or solid hydrocarbons. The feed stock (e.g. natural
gas, associated gas, coal-bed methane, residual (crude)
oil fractions and/or coal) is converted in a first step
into a mixture of hydrogen and carbon monoxide (this
15   mixture is often referred to as synthesis gas or syngas).
The synthesis gas is then fed into a reactor where it is
converted in a second step over a suitable catalyst at
elevated temperature and pressure into paraffinic
compounds ranging from methane to high molecular weight
20   molecules comprising up to 200 carbon atoms, or, under
particular circumstances, even more.

Numerous types of reactor systems have been developed
for carrying out the Fischer-Tropsch reaction. For
example, Fischer-Tropsch reactor systems include fixed
25   bed reactors, especially multi tubular fixed bed
reactors, fluidised bed reactors, such as entrained
fluidised bed reactors and fixed fluidised bed reactors,
and slurry bed reactors such as three-phase slurry bubble
columns and ebulated bed reactors.

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The Fischer-Tropsch reaction is very exothermic and
temperature sensitive with the result that careful
temperature control is required to maintain optimum
operation conditions and desired hydrocarbon product
5   selectivity.

The heat transfer characteristics of fixed-bed
reactors, e.g. multi tubular fixed bed reactors, are
generally poor because of the relatively low mass
velocity, small particle size and low thermal capacity of
10   fluids. If one attempts, however, to improve the heat
transfer by increasing the gas velocity, a higher CO
conversion can be obtained, but there is an excessive
pressure drop across the reactor, which limits commercial
viability. In order to obtain the CO conversions desired
15   and gas through-puts of commercial interest, the
conditions result in substantial radial temperature
gradients. For that reason, the Fischer-Tropsch fixed-bed
reactor tubes should have a diameter of less than 7 or
even 5 cm to avoid excessive radial temperature profiles.
20   The desired use of high-activity catalysts in Fischer-
Tropsch fixed-bed reactors makes the situation even
worse. The poor heat transfer characteristics make local
runaways (hotspots) possible, which may result in local
deactivation of the catalyst. In order to avoid runaway
25   reaction the maximum temperature within the reactor must
be limited. However, the presence of temperature
gradients within the reaction mixture means that much of
the catalyst may be operating at sub-optimal levels.

The use of liquid recycles as a means of improving
30   the overall performance in a fixed-bed design has been
described. Such a system is also called a "trickle bed"
reactor (as part of a sub set of fixed-bed reactor
systems) in which both reactant gas and liquid are

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introduced (preferably in a down flow orientation with
respect to the catalyst) simultaneously. The presence of
the flowing reactant gas and liquid improves the reactor
performance with respect to CO conversion and product
5   selectivity. A limitation of the trickle bed system (as
well as of any fixed-bed design) is the pressure drop
associated with operating at high mass velocities. The
gas-filled voidage in fixed-beds (typically less than
0.50) and size and shape of the catalyst particles does
10   not permit high mass velocities without excessive
pressure drops. Consequently, the mass through-put
undergoing conversion per unit reactor volume is limited
due to the heat transfer rates. Increasing the individual
catalyst particle size may slightly improve the heat
15   transfer by allowing higher mass velocities (for a given
pressure drop), but the loss in selectivity towards the
high boiling point products and the increase in methane
selectively combined with the increase in catalyst
activity generally offset the commercial incentives of
20   higher heat transfer.

Three-phase slurry bubble column reactors generally
offer advantages over the fixed-bed design in terms of
heat transfer characteristics. Such reactors typically
incorporate small catalyst particles suspended by upward
25   flowing gas in a liquid continuous matrix. A plurality of
cooling tubes are present in three phase slurry systems.
The motion of the continuous liquid matrix allows
sufficient heat transfer to achieve a high commercial
productivity. The catalyst particles are moving within a
30   liquid continuous phase, resulting in efficient transfer
of heat generated from catalyst particles to the cooling
surfaces, while the large liquid inventory in the reactor
provides a high thermal inertia, which helps prevent

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rapid temperature increases that can lead to thermal runaway.

One or more gas spargers, typically situated at or near the bottom of the suspension zone, should ensure adequate distribution of the feed gas through the suspension zone. Examples of known gas spargers are a porous plate and an arrangement of porous tubes. The pores in the plate or tubes are large enough to ensure adequate passage of gas, but small enough to prevent solid particles from entering the pores. However, significant clogging of pores may occur e.g. due to solid particles attrition or failure of the gas feed supply. Furthermore, the relatively small pores give rise to high pressure drops across the pores.

Other known gas spargers include dynamic gas jets, such as ejector jets and slit jets. Problems associated with such gas spargers include the danger of drainage of liquid/solid suspension from the suspension zone into the gas supply system in case of failure of the gas feed supply. This danger exists in those cases in which the gas outlets are situated above the gas supply system or at the same level of the gas supply system.

An overview of known gas spargers has been published in "Bubble Column Reactors" by W.-D. Deckwer, 1992, John Wiley & Sons, pages 9-13. Spargers are also described in EP-A-956126. In GB 787,123 an injection system is described using a line provided with simple nozzle or jets. The gas outlets, however, are at the same level of the injection line. Thus, a small pressure difference may result in the direct ingress of the slurry in the injection line.

The gas sparger of the present invention aims to solve problems associated with prior art gas spargers.

Thus, in the sparger system according to the present
situation the gas outlets (i.e. the openings where the
gas leaves the sparger system and is where the gas is
introduced into the slurry) are situated well below a gas
distribution system to avoid ingress of the slurry into
the distribution system. In this respect it is observed
that the ingress of slurry may result in depositions of
catalyst particles inside the sparger system. In the
absence of liquid heat transfer medium, and in the
presence of the large amounts of hydrogen and carbon
monoxide, the said catalyst particles or catalyst
deposits continue to catalyse the exothermic reaction. In
this way, local hot spots are created which may damage
the sparger system. In addition, coke deposits may be
formed. Especially after long run times during which
regularly ingress of slurry into the sparger system
occurs, considerable amounts of coke may be formed, which
could result in (partial) blockage of one or more pipes
in the sparger system. This should be avoided.

Accordingly, the present invention provides a sparger
system for use in a reactor, the sparger system
comprising a gas outlet for passing gas into the reactor,
and a gas distribution system to supply the gas to the
outlet, wherein the gas distribution system feeding a
sparger with gas to be ejected from the gas outlet is
disposed above the sparger outlet in the system.

The sparger system is typically useful in reactors
for carrying out exothermic reactions.

Typically the sparger outlet is disposed as close as
possible to the floor of the reactor, typically at a
distance of 20 cm or less, and more preferably at a
distance of 10 cm or less. In addition, all sparger gas
outlets are suitably situated at least 15 cm below the

distribution system, preferably all sparger outlets are
situated at least 30 cm below the distribution system.
Usually the sparger outlets are between 0.5 and 5 m below
the distribution system, preferably between 1 and 3 m.
Usually the sparger and the sparger outlets are at about
the same level in the reactor. Suitably the height
difference in a (vertical) reactor between the centre of
the central space of the sparger is less than 40 cm,
preferably less than 30 cm, more preferably less than
20 cm.

The gas distribution system suitably comprises an
arrangement of pipes to provide gas to the spargers. An
examples is a (large) horizontal distributor pipe
provided with a plurality of (small) horizontal side
pipes, each side provided with one or more vertical pipes
which are connected to the spargers, which spargers are
situated close to the bottom of the reactors. Another
example in a horizontal circular distributor pipe
provided with a plurality of vertical pipes, which end
close to the bottom of the reactor, the vertical pipes at
the end connected with e.g. two or four horizontal pipes
which are connected to the spargers. Other examples are
shown in the figures. The gas distribution systems are
provided with a gas supply pipe which is connected
through the reactor wall with an external gas supply
system. The connection via the reactor wall is suitably
at the same level of e.g. the horizontal distributor
pipe, but is preferably at a higher level. Suitably the
gas supply connection via the reactor wall is 0.3 to 8 m
above the sparger outlets, preferably 0.5 to 5 m, more
preferably 1 to 3 m. In an exceptional case a long
elongated pipe may be used which enters the reactor at
the top. In some cases one gas supply pipe may be used,

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in other cases a plurality, e.g. 2-10, may be used. A
reactor may be provided with one sparger system or with a
plurality of sparger systems, e.g. 2 to 16, especially 4
to 12.

5   In the present application a sparger is a device that
introduces the gas via one or more sparger outlets into
the slurry. There is a central space which is in fluid
connection with the gas distribution means and in fluid
connection with the sparger outlets (or gas outlets). The
10   gas distribution means comprises the gas distribution
system and usually the distribution conduit means. The
spargers may be connected directly with the distribution
system or, preferably, via the distribution conduits. In
most situations the distribution system in one
15   (horizontal) plane, perpendicular to the (vertical)
reactor axis. The sparger is not a part of the
distribution system. Thus, a distribution system
consisting of a central distributor pipe provided with
gas outlet means does not fall within the scope of the
20   claims as no sparger is present.

The sparger systems according to the invention have
the advantage that no moving parts are necessary inside
the reactor. The gas flow can be controlled outside the
reactor. Thus, preferably no moving parts are present in
25   the reactor, or, all elements used are static elements.

Further, as the gas supply connection via the
reactor, which is the highest point of the gas
distribution system, is situated above the sparger
outlets, there is a natural barrier against inflow of
30   slurry into the spargers and the gas distribution system.
In a further preferred embodiment the gas supply
connections via the reactor wall are located in the
vertical cylindric reactor wall, preferably at least

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0.2 m, more preferably between 0.3 and 2 m above the
transition of the vertical cylindric wall into, usually
dome or spherically shaped, the bottom of the reactor.

The invention also provides a reactor incorporating a
sparger according to the above aspect of the invention.

In certain embodiments the sparger outlet is located
at the end of the sparger which is in turn at the end of
a distribution conduit feeding the gas to the sparger.

Typically the gas outlet is adapted to eject gas
across the floor of the reactor.

Sweeping the floor of the reactor with the gas
ejected from the sparger outlet has the advantage of
enhancing the distribution of the catalyst within the
reactor, improving mixing in the bottom of the reactor,
which is beneficial for the transfer of heat to the
cooling modules and avoids local hot spots. It also
disperses any particles of catalyst from the floor, which
avoids localised build-up of catalyst and localised
hotspots that can occur in that zone as a result.

In reactors that are particularly adapted for
carrying out exothermic reactions, and which have cooling
means to control the heat generated as a result of the
exothermic reactions, the sweeping of the catalyst from
the floor of the reactor therefore circulates the
catalyst only in the zone above the sparger outlets,
where coolant circulation tubes normally predominate in
such reactors, so that most of the exothermic reactions
occur in zones of the reactor that are dense in coolant
circulation tubes. This facilitates the control of the
reaction and reduces the liability for hotspots in areas
that are uncontrolled by cooling means.

The arrangement of the sparger outlet below the gas
distributor system also facilitates mixing and removal of

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heat in the lower areas of the reactor adjacent to the
floor of the reactor, and prevents build-up of wax or by-
products there, while also settling of catalyst is
prevented.

5   Typically the gas outlets are disposed parallel to or
directed towards the lower inner surface of the reactor.
Each sparger device typically has a number of outlets
(e.g. 6-12) directed outwardly from a sparger head, and
the outlets are typically arranged equidistantly from one
10   another around the periphery of the sparger head such
that gas jets leaving the outlets sweep the surrounding
area of the reactor uniformly. It would be possible for
the gas jet from the outlet to be oriented directly
towards the floor surface in some embodiments.

15   The sparger heads are typically spaced apart from one
another on the floor of the reactor in a regular pattern.
The pattern and density of the sparger heads, and the
speed of the gas jets leaving the sparger heads are
typically selected so that the gas jets have sufficient
20   radial penetration into the slurry surrounding the heads
to ensure sufficient coverage of the reactor cross-
section, but also so that the gas injection velocity is
limited to avoid catalyst attrition.

The gas outlets typically incorporate a flow
25   controlling means such as an orifice to regulate the
speed of the gas jet through the outlet. The orifices are
typically Venturi type orifices, and may optionally
incorporate a check valve to limit the flow of slurry
into the outlet. In order to limit the injection velocity
30   of the gas from the outlet and thereby reduce catalyst
attrition the outlet orifice is typically shrouded by a
larger diameter shroud pipe that extends beyond the
orifice for a minimum distance dependant on the desired

injection velocity and the dimensions of the sparger, so
that the kinetic energy of the gas jet leaving the
orifice is dissipated to some extent in the shroud pipe,
before entering the slurry. Typically the floor of the

5   reactor is concave and the positioning of straight gas
outlet shroud pipes generally parallel to a tangent on
the curve of the floor will normally involve the gas jets
being directed towards the floor as they leave the
outlet, thereby enhancing the sweeping function.

10   According to a further aspect, the invention provides
a method for carrying out a reaction comprising the steps
of charging a reactor with reactants and removing the
reaction products from the reactor, wherein at least some
of the reactants are fed into the reactor via a sparger

15   device, which ejects the reactants through an outlet, and
wherein the sparger device is fed with reactants via a
distribution system that is disposed above the sparger.

Another possibility to remove any catalyst particles
present in the sparger system in the injection of

20   suitable liquids into the gas stream that flows through
the sparger system. This can be done intermittently or
continuously. Suitable injection liquids are
hydrocarbons, especially hydrocarbons made in a Fischer-
Tropsch process. Directly obtained hydrocarbons may be

25   used, e.g. reactor wax obtained via filtration of the
slurry, or distillate fractions, distilling in the range
between 120 and 500 °C, especially between 150 and
360 °C. Also hydrogenated and/or hydrocracked fractions
may be used, these fractions boiling between 120 and

30   500 °C, especially between 150 and 360 °C. These
injection liquids are preferably injected via an
injection nozzle outside the reactor. Due to the fact
that the flow pattern of the gas in the sparger system is

downwardly directed, the injected liquid will wash away
any catalyst particles and/or catalyst deposits which may
be present in the system. In a preferred embodiment the
injection liquid is heated to a temperature between 100

5   and 250 °C, more preferably between 150 and 225 °C.

Without wishing to be restricted to a particular
embodiment, the invention will now be described in
further detail with reference to the drawings in which:

Figure 1 is a side view of a general arrangement of a

10   reactor having a sparger system;

Figure 2 is plan view of the spargers at the base of
the Fig. 1 reactor;

Figure 3 is a side view of the Fig. 2 spargers;

Figure 4 is a plan view of the sparger pipework;

15   Figure 5 is a side view of the sparger pipework; and

Figure 6 is a side view of a sparger head.

Turning now to Figure 1 a reactor 20 has an outer
shell 21 defining a chamber into which reactants are
delivered. The reactor in this embodiment is typically

20   used for carrying out three phase slurry reactions, such
as for example Fisher Tropsch type reactions. Liquid
phase reactants and solid particulate catalyst are fed
into the reactor chamber from feed pipes (not shown), and
gas phase reactants are delivered into the reactor by

25   means of an arrangement of gas spargers 15 disposed on
the floor of the reactor. The spargers 15 have outlets
that emit bubbles of gas which rise in the liquid phase
and interact with the solid particulate catalyst in the
liquid phase to form reaction products, which are removed

30   from the reactor.

Since the Fischer-Tropsch reaction is exothermic, the
reactor 20 houses a number of cooling modules 1 (only one
shown for clarity) for delivering and circulating coolant

through the circulation system of coolant pipes within
the reactor shell 21. Cooling modules 1 are supported
from below by saddles resting on the floor of the reactor
shell 21. Heat is transferred from the slurry surrounding

5   the cooling modules 1 to the coolant as it passes through
the circulation system of the module. Suitable coolants
will be known to the person skilled in the art and
include for example water/steam or oil based coolants.

Synthesis gas (or syngas) is preferably fed into the

10 reactor at a low level in the reactor, optionally as
close as possible to the short-radius zone of the dished
floor of the reactor, as shown in Fig. 3, provided that
this is above the syngas outlets into the reactor 20.
External syngas feed pipes can be connected to flanges on

15 the shell 21 at the point of entry to the reactor by
means of c-clamps 5 of the same design used to connect
coolant pipework, thereby minimising design variations
throughout the reactor. Syngas is then fed via
distributor pipes 10 (clamped together at the flanges by

20 means of c-clamps 5) to a gas manifold 11 at the floor of
the reactor 20. Each manifold 11 is fed by a single
distributor pipe in the example shown, but a single
distributor pipe could feed a number of manifolds if
desired. Each manifold 11 is connected to and supports a

25 number of spargers 15 (e.g. four) which it feeds with
syngas via sparger feed tubes 12. Sparger feed tubes 12
are connected to the spargers by means of the c-clamps 5.

The spargers 15 are arranged in a uniform pattern
over the floor of the reactor 20 as shown in Fig. 5, and

30 are typically arranged around the saddles 23. Each
sparger 15 has central chamber 16 with eight orifices 17.
Each of the orifices is connected via a narrow Venturi-
type throat to a shroud pipe 18 with a wider diameter and

having an outlet 19 to the reactor. Each shroud pipe 18
is arranged parallel to the floor of the reactor
shell 21. In some embodiments the shroud pipes 18 can be
directed at a shallow angle toward the floor of the

5   reactor shell 21.

In operation, syngas is fed through the distributor
pipes 10 into the manifolds 11 and sparger feed pipes 12
and into the spargers 15. Through the central chamber of
the sparger 16, the syngas is distributed uniformly

10   through the orifices 17 and Venturis and into the shroud
pipes 18. The Venturi restricts the entrance of slurry
(and especially catalyst) into the orifice.

Optionally a check valve (not shown) may be located
at some point in the gas feed or distribution system

15   (typically outside the reactor so that moving parts are
kept out of the reactor shell) in order to prevent
catalyst penetration into the syngas distribution system.

Bends in the manifolds 11 are preferably avoided if
possible but are occasionally necessary to connect the

20   manifold with each sparger 15. In that event, bends are
typically made in the horizontal plane of the manifold,
rather than in the vertical plane, as shown in Fig. 5.
This maximises downflow in the gas feed distribution
system to the spargers 15, which has the advantage of

25   reducing the slurry ingress into the feed system. This
limits further the catalyst entry into the gas feed
system and consequential fouling, blockages and
uncontrolled heat production due to the exothermic
reaction between the liquid reactants in the slurry and

30   the syngas in the feed system. Small backflows of slurry
into the spargers 15 or the feed pipes can be combated by
maintaining the positive pressure of the gas, and by
occasional purging of the gas feed system.

The gas jets leaving the Venturi dissipate to some
extent in the shroud pipes 18 due to the wider diameter
and the length of the shroud pipe 18, until regular flow
develops in the shroud pipe 18 downstream of the Venturi.

5   Larger pipes can be used to reduce the injection velocity
and pressure accordingly. The diameter and length of the
shroud pipe 18 is chosen in conjunction with the desired
gas injection velocity and the pattern and number of
spargers to reduce the exit velocity from the outlet of

10   the pipe 18 to an acceptable level that is high enough to
ensure adequate radial penetration of the gas into the
slurry to achieve the effects of catalyst dispersion from
the floor of the reactor, but low enough so as to avoid
excessive catalyst attrition. In this example, which is

15   representative for the standard use of the reactor and
the sparger system, the syngas flow at the inlet to the
distribution system is around 5-10 m^3/sec at reaction
conditions. The diameter of the orifice 17 is around
30-40 mm and the shroud pipe 18 is at least 200 mm long

20   and has an ID of around 40-60 mm. Feed gas velocity
across the spargers is limited to a maximum of around
5-15 m/s. It will be understood that these figures are
optional and not limiting.

The spargers 15 in this embodiment each have eight

25   outlets 19, and are arranged in a regular pattern of
32 spargers across the floor of the reactor 20. This
arrangement ensures that substantially the whole of the
floor of the reactor is uniformly fed with syngas at a
slight overpressure with respect to the rest of the

30   reactor contents, which avoids the settling of catalyst.

In preferred embodiments the spargers are positioned
at the same distance from the bottom of the reactor, e.g.
either physically supported on the reactor floor, or

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(preferably) supported from above a few mm above it on
the feed pipes 12. This means that with reactor shells
having concave floors there will be a slight hydrostatic
pressure difference between those spargers at the central
5   axis of the reactor, where the concave surface is the
deepest, and those at the periphery of the floor, near
the transition between the floor surface and the wall of
the reactor shell 21. This hydrostatic pressure
difference can affect the uniformity of the gas
10   distribution from the sparger 15, and to compensate for
this effect, the floor of the reactor shell 21 typically
has a 1:2 height/diameter ratio. Also the orifices of the
spargers 15 in the centre of the reactor (or elsewhere)
are typically modified to equalise the gas jet velocity
15   and pressure over all of the spargers 15 in the
reactor 20.

Typically the sparger feed tubes 11 have a relatively
wide diameter in order to avoid pressure losses in the
distribution system affecting the gas jet velocity from
20   the spargers 15.

In preferred embodiments the spargers are positioned
in between the saddles 3 for supporting the cooling
modules as shown in Fig. 5, and are fed from above via
feed pipes 10 that are as straight as possible. This
25   configuration helps the sparger outlets 19 to be
positioned very close to the floor of the reactor
shell 21, as no feed pipework or support structure needs
to be located between the sparger and the floor of the
reactor. In this example the sparger outlets 19 are less
30   than 10 cm (e.g. 5 cm) above the floor of the shell 21.
The sparger distribution pattern on the floor of the
reactor 20 is typically chosen to match as far as
possible the pattern of the cooling modules in the

reactor (shown as an outline shape in Fig. 4), so that
the reaction between the injected syngas and the other
reactants in the presence of the suspended catalyst takes
place as far as possible in the vicinity of the cooling

5   modules. This helps to reduce reaction hotspots where too
much syngas is added to one particular area for the
cooling capacity of that area to control the reaction.

In preferred embodiments the spargers 15 are
identical and interchangeable, and the same c-clamp

10   connections are used on flanged pipes throughout the
reactor.

Modifications and improvements can be incorporated
without departing from the scope of the invention. For
example, the average particle size of the catalyst

15   particles may vary between wide limits, depending inter
alia on the type of slurry zone regime. Typically, the
average particle size may range from 1 μm to 2 mm,
preferably from 1 μm to 1 mm.

If the average particle size is greater than 100 μm,

20   and the particles are not kept in suspension by a
mechanical device, the slurry zone regime is commonly
referred to as ebulating bed regime. Preferably, the
average particle size in an ebulating bed regime is less
than 600 μm, more preferably in the range from 100 to

25   400 μm. It will be appreciated that in general the larger
the particle size of a particle, the smaller the chance
that the particle escapes from the slurry zone into the
freeboard zone. Thus, if an ebulating bed regime is
employed, primarily fines of catalyst particles will

30   escape to the freeboard zone.

If the average particle size is at most 100 μm, and
the particles are not kept in suspension by a mechanical
device, the slurry zone regime is commonly referred to as

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a slurry phase regime. Preferably, the average particle
size in a slurry phase regime is more than 5 μm, more
preferably in the range from 10 to 75 μm.

If the particles are kept in suspension by a
mechanical device, the slurry zone regime is commonly
referred to as stirred tank regime. It will be
appreciated that in principle any average particle size
within the above ranges can be applied. Preferably, the
average particle size is kept in the range from 1 to
200 μm.

The concentration of catalyst particles present in
the slurry may range from 5 to 45% by volume, preferably,
from 10 to 35% by volume. It may be desired to add in
addition other particles to the slurry, as set out in for
example European Patent Application Publication
No. 0 450 859. The total concentration of solid particles
in the slurry is typically not more than 50% by volume,
preferably not more than 45% by volume.

Suitable slurry liquids are known to those skilled in
the art. Typically, at least a part of the slurry liquid
is a reaction product of the exothermic reaction.
Preferably, the slurry liquid is substantially completely
a reaction product.

The exothermic reaction is a reaction which is
carried out in the presence of a solid catalyst, and
which is capable of being carried out in a three-phase
slurry reactor. Typically, at least one of the reactants
of the exothermic reaction is gaseous. Examples of
exothermic reactions include hydrogenation reactions,
hydroformylation, alkanol synthesis, the preparation of
aromatic urthanes using carbon monoxide, Kölbel-
Engelhardt synthesis, polyolefin synthesis, and Fischer-
Tropsch synthesis. According to a preferred embodiment of

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the present invention, the exothermic reaction is a
Fischer-Tropsch synthesis reaction.

The Fischer-Tropsch synthesis is well known to those
skilled in the art and involves synthesis of hydrocarbons
5   from a gaseous mixture of hydrogen and carbon monoxide,
by contacting that mixture at reaction conditions with a
Fischer-Tropsch catalyst.

Products of the Fischer-Tropsch synthesis may range
from methane to heavy paraffinic waxes. Preferably, the
10   production of methane is minimised and a substantial
portion of the hydrocarbons produced have a carbon chain
length of a least 5 carbon atoms. Preferably, the amount
of C5+ hydrocarbons is at least 60% by weight of the
total product, more preferably, at least 70% by weight,
15   even more preferably, at least 80% by weight, most
preferably at least 85% by weight.

Fischer-Tropsch catalysts are known in the art, and
typically include a Group VIII metal component,
preferably cobalt, iron and/or ruthenium, more preferably
20   cobalt. Typically, the catalysts comprise a catalyst
carrier. The catalyst carrier is preferably porous, such
as a porous inorganic refractory oxide, more preferably
alumina, silica, titania, zirconia or mixtures thereof.

The optimum amount of catalytically active metal
25   present on the carrier depends *inter alia* on the specific
catalytically active metal. Typically, the amount of
cobalt present in the catalyst may range from 1 to
100 parts by weight per 100 parts by weight of carrier
material, preferably from 10 to 50 parts by weight per
30   100 parts by weight of carrier material.

The catalytically active metal may be present in the
catalyst together with one or more metal promoters or co-
catalysts. The promoters may be present as metals or as

the metal oxide, depending upon the particular promoter concerned. Suitable promoters include oxides of metals from Groups IIA, IIIB, IVB, VB, VIB and/or VIIB of the Periodic Table, oxides of the lanthanides and/or the actinides. Preferably, the catalyst comprises at least one of an element in Group IVB, VB and/or VIIB of the Periodic Table, in particular titanium, zirconium, manganese and/or vanadium. As an alternative or in addition to the metal oxide promoter, the catalyst may comprise a metal promoter selected from Groups VIIB and/or VIII of the Periodic Table. Preferred metal promoters include rhenium, platinum and palladium.

A most suitable catalyst comprises cobalt as the catalytically active metal and zirconium as a promoter. Another most suitable catalyst comprises cobalt as the catalytically active metal and manganese and/or vanadium as a promoter.

The promoter, if present in the catalyst, is typically present in an amount of from 0.1 to 60 parts by weight per 100 parts by weight of carrier material. It will however be appreciated that the optimum amount of promoter may vary for the respective elements which act as promoter. If the catalyst comprises cobalt as the catalytically active metal and manganese and/or vanadium as promoter, the cobalt : (manganese + vanadium) atomic ratio is advantageously at least 12:1.

The Fischer-Tropsch synthesis is preferably carried out at a temperature in the range from 125 to 350 °C, more preferably 175 to 275 °C, most preferably 200 to 260 °C. The pressure preferably ranges from 5 to 150 bar abs., more preferably from 5 to 80 bar abs.

Hydrogen and carbon monoxide (synthesis gas) is typically fed to the three-phase slurry reactor at a

molar ratio in the range from 0.4 to 2.5. Preferably, the hydrogen to carbon monoxide molar ratio is in the range from 1.0 to 2.5.

The gaseous hourly space velocity may very within wide ranges and is typically in the range from 1500 to 10000 Nl/l/h, preferably in the range from 2500 to 7500 Nl/l/h.

The Fischer-Tropsch synthesis is preferably carried out in a slurry phase regime or an ebulating bed regime, wherein the catalyst particles are kept in suspension by an upward superficial gas and/or liquid velocity.

It will be understood that the skilled person is capable to select the most appropriate conditions for a specific reactor configuration and reaction regime.

Preferably, the superficial gas velocity of the synthesis gas is in the range from 0.5 to 50 cm/sec, more preferably in the range from 5 to 35 cm/sec.

Typically, the superficial liquid velocity is kept in the range from 0.001 to 4.00 cm/sec, including liquid production. It will be appreciated that he preferred range may depend on the preferred mode of operation.

According to one preferred embodiment, the superficial liquid velocity is kept in the range from 0.005 to 1.0 cm/sec.